E.B. WIKEN, T.W. PIERCE, AND G.R. IRONSIDE

Lands Directorate, Environment Canada

Ottawa, Ontario

K1A 0E7

ABSTRACT

MULTISTAGE REMOTE SENSING IN EXPLORATORY ECODISTRICT LAND CLASSIFICATION

by E.B.Wiken, T.W. Pierce and G.R. Ironside

Presented at the Sixth Canadian Symposium on Remote Sensing, may 21-23, 1980 Halifax, Nova Scotia.

Pam: 528.7:(*41N) WIK

POLAR PAM 1559 POLARPAM

BOREAL INSTITUTE LIBRARY

MULTISTAGE REMOTE SENSING IN EXPLORATORY ECODISTRICT LAND CLASSIFICATION

by E.B.Wiken, T.W. Pierce and G.R. Ironside

Presented at the Sixth Canadian Symposium on Remote Sensing, May 21-23, 1980 Halifax, Nova Scotia.

*MULTISTAGE REMOTE SENSING IN EXPLORATORY ECODISTRICT LAND CLASSIFICATION

E.B. WIKEN, T.W. PIERCE, AND G.R. IRONSIDE

Lands Directorate, Environment Canada

Ottawa, Ontario

K1A 0E7

ABSTRACT

Much of the Northwest Territories remains a question mark in relation to its total land resource complement. The Northern Land Use Information Series is one program which is attempting to provide broad but consistent coverage of northern land resources at a scale of 1:250,000. This map series includes, among other topics, an ecological overview of terrestrial ecosystems. The ecological land classification system is employed, with its focus being the mapping and description of ecodistricts.

The ecological input requires the classification and description of very extensive areas, in a relatively short time, and with a low budget. A technique involving the visual interpretation of multistage remote sensing makes this possible. The combined use of LANDSAT, aerial photographs, and 35 mm color slides has proven to be effective and efficient in the prefield, field, and postfield activities of the ecological land classification. The benefits have included: improved map boundary definition and ecodistrict descriptions; reduced time, material and manpower inputs; and improved field reconnaissance work through better direction to the various ecodistricts as well as to representative locales within each.

* Presented at the Sixth Canadian Symposium on Remote Sensing, 21 to 23 May 1980, Halifax, Nova Scotia.

Rec'd: Dec 17/80
Order No.:
Price: WF
Acc. No.: Lands Directorate, Ottawa

43849 BOREAL INSTITUTE LIBRARY

INTRODUCTION

The Yukon Territory and the Northwest Territories together comprise 3,916,000 km^2 or 39.3% of the total area of Canada. However, even rudimentary information is lacking for most of the area, thus posing a severe hindrance to the preparation of comprehensive land use plans for the north. Any baseline information program for this immense area would have to cover large blocks of land each year at a generalized level to be reasonably timely for evaluating proposed land uses. Such a baseline program is the Northern Land Use Information Series (NLUIS) of maps which is jointly sponsored by Environment Canada and Indian and Northern Affairs Canada. Established in 1971, this program collects and compiles data on the biological, physical, social, cultural, and economic characteristics of the territories. Presented on 1:250,000 scale descriptive maps, the results, in part, comprise the base for making environmental planning and management decisions.

As one component of the maps, the Ecological Land Classification and Evaluation Division of the Lands Directorate (Environment Canada) provides information on ecodistricts — intermediate level terrestrial ecosystems. This input was initially started in 1976. Prior to this date, the focus was on either physiography or a recreation-terrain evaluation. Because of the constraints inherent in rapid, low-cost environmental surveys, such as the Northern Land Use Information Series, ecodistricts are derived mostly through the use of multistage remote sensing coupled with limited field checking. This paper discusses the application of this simple interpretive technique as it applies to exploratory ecodistrict land classification in the north. Much of the multistage sampling is linked to LANDSAT imagery.

METHODOLOGY

The methodology for the ecological component of the NLUIS program involved an ecodistrict land classification approach and a multistage remote sensing technique. The concepts behind ecodistrict land classification will only briefly be discussed here as the approach is outlined elsewhere (Wiken, 1980; Wiken and Welch, 1979). This paper will, however, detail the multistage remote sensing technique used to achieve the classification.

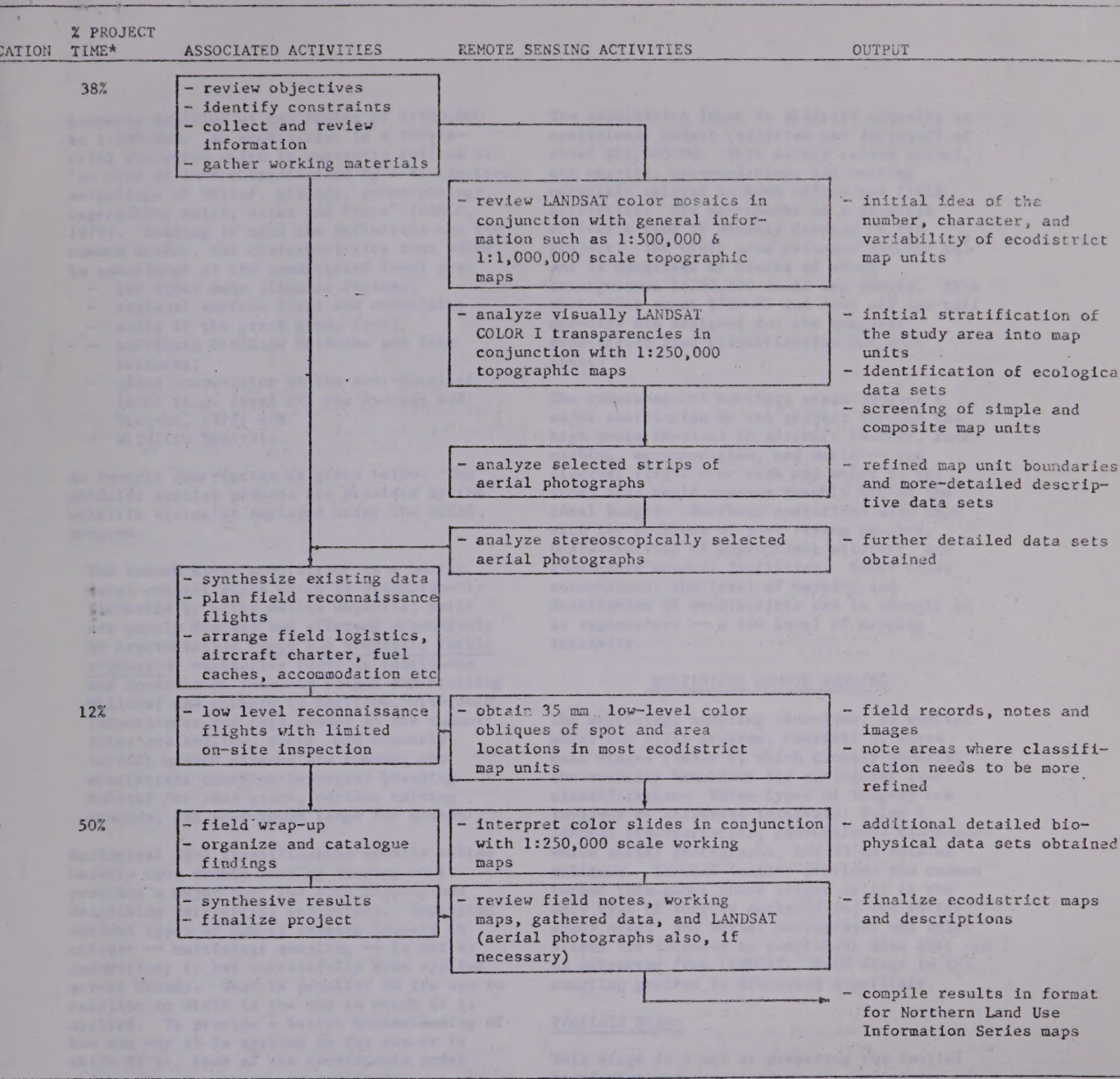
Ecodistrict Land Classification

Ecodistricts are one of several levels of generalization contained within the ecological land classification system (Table 1). As the table suggests, it is an intermediate level

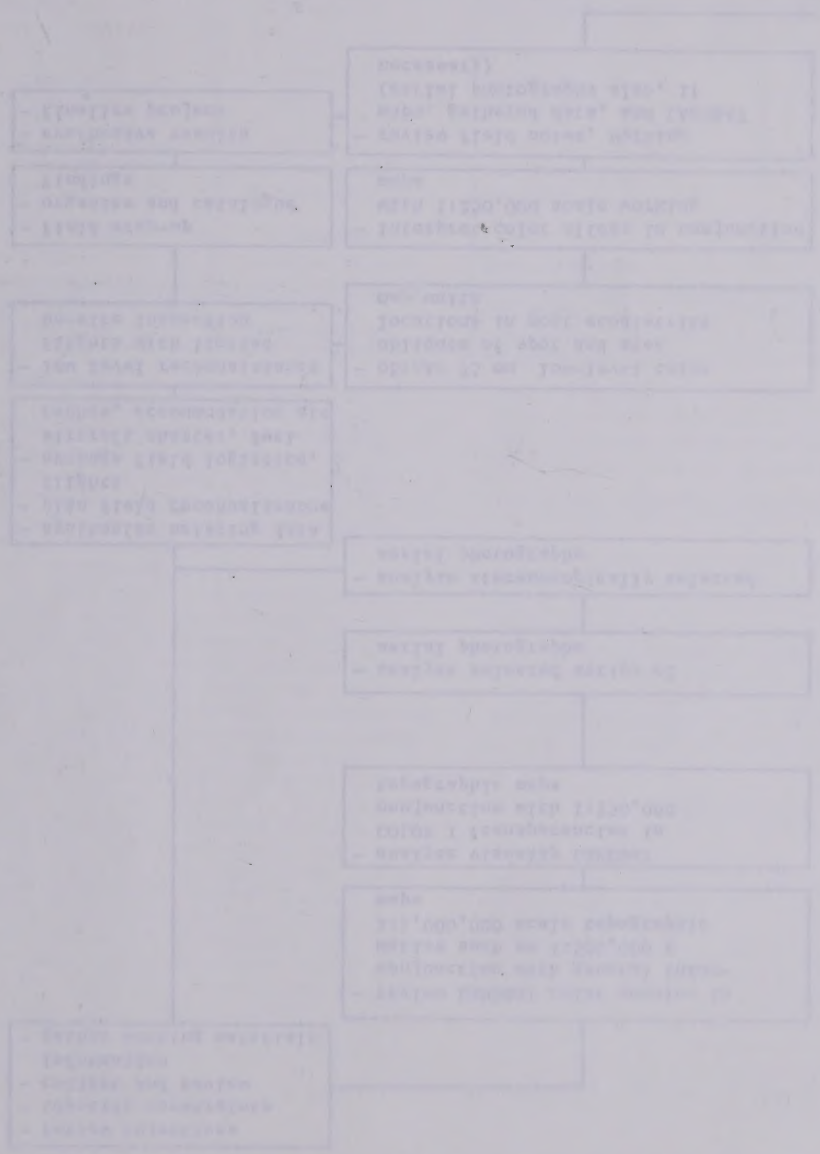
Ecological Land Classification System	Associated Map Scales	Associated Planning Framework	Associated Remote Sensing Used
Ecoprovince	1:10,000,000 to 1:5,000,000	International	LANDSAT
Ecoregion	1:3,000,000 to 1:1,000,000	National to international	LANDSAT & high altitude aerial photographs
Ecodistrict	1:500,000 to 1:250,000	Regional to national	High altitude aerial photographs & LANDSAT
Ecosection	1:250,000 to 1:100,000	Municipal to subregional	Conventional aerial photographs (1:50,000)
Ecosite	1:50,000 to 1:10,000	Local	Low level aerial photographs (1:25,000)
Ecoelement	1:10,000 to 1:2,500	Detailed	Detailed aerial photographs

Table 1: Ecological land classification and associated factors.

he multistage sampling technique as applied under the Northern Land Use Information Series Program.


CATION
% PROJECT TIME*
ASSOCIATED ACTIVITIES
REMOTE SENSING ACTIVITIES
OUTPUT
38%
- review objectives
- identify constraints
- collect and review information
- gather working materials
- review LANDSAT color mosaics in conjunction with general information such as 1:500,000 & 1:1,000,000 scale topographic maps
- initial idea of the number, character, and variability of ecodistrict map units
- analyze visually LANDSAT COLOR I transparencies in conjunction with 1:250,000 topographic maps
- initial stratification of the study area into map units
- identification of ecological data sets
- screening of simple and composite map units
- analyze selected strips of aerial photographs
- refined map unit boundaries and more-detailed descriptive data sets
- analyze stereoscopically selected aerial photographs
- further detailed data sets obtained
- synthesize existing data
- plan field reconnaissance flights
- arrange field logistics, aircraft charter, fuel caches, accommodation etc
12%
- low level reconnaissance flights with limited on-site inspection
- obtain 35 mm low-level color obliques of spot and area locations in most ecodistrict map units
- field records, notes and images
- note areas where classification needs to be more refined
50%
- field wrap-up
- organize and catalogue findings
- interpret color slides in conjunction with 1:250,000 scale working maps
- additional detailed biophysical data sets obtained
- synthesive results
- finalize project
- review field notes, working maps, gathered data, and LANDSAT (aerial photographs also, if necessary)
- finalize ecodistrict maps and descriptions
- compile results in format for Northern Land Use Information Series maps

es the relative percentage of the six man-months allotted to the project in total



commonly depicted at map scales of 1:500,000 to 1:250,000. An ecodistrict is a terrestrial ecosystem which is currently defined as "an area of land characterized by a distinctive assemblage of relief, geology, geomorphology, vegetation, soils, water and fauna" (CCELC, 1979). Bearing in mind the definition and the common scales, the characteristics that would be considered at the ecodistrict level are:

- low order meso climatic regimes;
- regional surface forms and materials;
- soils at the great group level;
- sub-basin drainage networks and lake features;
- plant communities at the semi-detailed level (e.g. level IV: see Dyrness and Viereck, 1979; and
- wildlife habitats.

An example description is given below. The wildlife species present are provided by the wildlife biologist employed under the NLUIS program.

> The Armark River ecodistrict is a nearly level coastal plain which is predominantly blanketed by silty marine deposits; soils are poorly drained and affected extensively by cryoturbation (rego and gleysolic turbic cryosols); vegetative cover is continuous and consists of tussocky sedges and trailing willows; the climate is maritime, with cold temperatures and fogs common in the summer; lakes are shallow, ovoid, and commonly turbid; beaded streams are common; the ecodistrict contains important breeding habitat for snow geese, caribou calving grounds, and year-round range for muskox.

Ecological land classification usually relies heavily upon remote sensing imagery — it provides a major tool for both mapping and describing terrestrial ecosystems. Employing various types of remote sensing imagery in concert — multistage sampling — is not an innovation; it has successfully been applied across Canada. What is peculiar to its use in relation to NLUIS is the way in which it is applied. To provide a better understanding of how and why it is applied in the manner in which it is, some of the constraints under which we must operate are outlined.

Operational Constraints

The technique which evolved for mapping and describing ecodistricts reflects the following operational constraints: low budget; high cost of working in and remoteness of northern areas; short time-frame for mapping and describing ecodistricts; limited manpower; and vastness of the area.

The ecodistrict input is allotted annually an operational budget (salaries not included) of about $21,000.00. This mainly covers travel, air charter, accommodation, and working materials related to both office and field activities. Six man-months of a research officer's time is usually devoted to the project. The study area averages 246,000 km^2 and is comprised of blocks of about twenty-seven 1:250,000 scale map sheets. This means that about $780.00 and four and one-half man-days are assigned for the complete ecodistrict land classification for each sheet.

The remoteness of northern areas imposes a major restriction on the project through the high costs involved in aircraft charter, fuel caching, accommodation, and meals -- one diagonal flight over each map sheet in the study area would consume roughly 90% of the total budget. Northern operations also cope with the problems of poor flying weather, unavailability of appropriate aircraft, and inadequate support facilities. Under these constraints, the level of mapping and description of ecodistricts can be thought of as exploratory — a low level of mapping intensity.

MULTISTAGE REMOTE SENSING

The multistage sampling technique, as applied under the NLUIS program, consists of three main stages (Table 2) which closely parallel the activity breakdown for ecological land classification. Three types of imagery are involved at different intervals: Color I LANDSAT transparencies, conventional black-and-white aerial photographs, and 35 mm colored obliques. LANDSAT imagery provides the common thread throughout these stages as it is the only type of imagery analyzed for the entire study area. The aerial photographs and color slides are intended to complement data that can be extracted from LANDSAT. Each stage in the sampling process is discussed separately.

Prefield Stage

This stage is aimed at preparing the initial boundaries and descriptions of ecodistrict map units. Background literature, as a start, is collected and reviewed to assist in this work. Information secured, while usually scarce, yields some indication of what to expect within the study area as well as often providing benchmark sites for extrapolation purposes during the analysis of imagery.

It is relevant at this point to discuss some of the options regarding the types of imagery one might choose. For an average study area,

there are somewhere in the order of 8,500 aerial photographs (approximate scale of 1:60,000). If even only 10 minutes were spent on each pair, it would easily exceed 1,000 man-hours of work — an impossible option with only 900 man-hours available in total. Also, the commonly available aerial photographs for the north are paradoxically too detailed to readily characterize ecodistricts within the time frame allowed. Total reliance on LANDSAT would also be an impractical option as certain kinds of data required for ecodistricts cannot be extracted from this source alone. An alternative route is to employ both and economize on time but not sacrifice required data. LANDSAT imagery is analyzed to generate the initial map unit boundaries and descriptions on physical and, to a lesser degree, biological data sets. As a follow-up, strips of aerial photography flights are examined to confirm and modify map unit lines and to gather further biological and physical data sets.

LANDSAT analysis is geared to Color I transparencies as these have empirically been found to be superior. Frames taken with less than ten percent cloud cover and during the late spring or early summer period are preferred. This period coincides with the time when hydrological, terrain, and floristic properties tend to be the most marked and when the field work is carried-out. Once purchased, the frames are arranged as a mosaic and visually examined in conjunction with 1:1,000,000 and 1:500,000 topographical maps. The topographical maps are necessary to highlight some of the surface form information which is not always apparent on the frames. An indication of the total number, complexity, spatial extent, character, and range of ecodistricts can be quickly attained and some idea of the work load involved can be ascertained. The individual frames are then more closely examined in relation to the more detailed working maps. Map unit boundaries are drawn on a 1:250,000 topographical map base and preliminary descriptions are made. Descriptors such as the extent, surface expression, and mix of terrain features can be surmized. The size, form, and distribution of regional water features can be easily interpreted. General vegetative cover is also discernable. These features are intricately linked and the means by which they are diagnosed will be expanded upon later in this paper.

The features associated with each ecodistrict map unit can range from something fairly uniform to something very mixed. Ecodistrict map unit A (Figure 1.1) could, relatively speaking, be termed simple in that the evenness of the same color and the lack of multiple forms (shape of colored areas) suggests uniformity. Units B, C, D, and E are composite types in which the occurrences of biological and physical characteristics are fairly variable and can be fairly recurrent or irregular in their spatial location within a map unit. LANDSAT provides good indications of the kinds of map units present and, in doing so, provides the basis for economizing efforts with the aerial photograph analysis. The "simple" map units are given less attention and effort.

To complete the prefield descriptions and boundary locations, we rely on black-and-white aerial photographs; the smallest scale readily available for the north is roughly 1:60,000, dating mainly from the early 1950's. Imagery analysis here primarily centres on obtaining information on the more localized features which comprise the ecodistrict map unit. Local landforms, patterned ground phenomena, plant communities, wetlands, streams and ponds, seepage zones, drainage conditions, bedrock types, etc. are some examples. Aerial photograph analysis also provides a check on or further resolution of boundaries depicted through LANDSAT work.

Purchasing aerial photographs is impractical considering the budget; the cost would be close to $13,000. To overcome this, we rely on the National Air Photo Library (NAPL) collection. Both the black-and-white prints and the microfiche collections are utilized in the strip analysis of each ecodistrict map unit. To give a general indication, approximately two 1:250,000 sheets are handled each day. Each map sheet has an average of five different map units; so, in a 7.5 hour working day, about 23 minutes can be spent on aerial photography for each map unit. In practise, there is a great deal of judgement called for on the interpreter's part to weight this time according to whether a "simple" or more "composite" unit is being examined. Since most map units extend over three or four map sheets, the time spent on each map unit in total is cumulative.

The location for strip analysis is determined largely from the LANDSAT analysis. Areas which appear to be representative, boundaries which are uncertain, and areas that require a more detailed examination control this selection. The constructiveness of this stratification hinges upon the experience of the interpreter. Microfiche viewing provides a quick strip analysis and little time is spent on obtaining and handling copies. Although there is a loss in resolution and stereoscopic viewing is not possible, it allows the interpreter to examine lengthy strips quickly.

Microfiche screening offers another mode to isolate areas in which it would be information-effective to stereoscopically interpret hard print copies of aerial photographs.

The information retrieved from LANDSAT and aerial photograph analysis assists in planning for the field stage. From the information derived, we can optimize our efforts by having field work in representative as well as in the maximum number of different map units.

Field Stage

The field stage includes a low-level reconnaissance flight and selected ground checks. The dilemma faced with aircraft is whether to use a helicopter or a fixed-wing. A helicopter offers unlimited ground checking; however, it has a low range and so provides limited coverage and requires a great many fuel caches. A fixed-wing provides greater range and coverage, and thus requires fewer fuel caches; however, the possibilities of ground checking are more limited.

The main disadvantage of fixed-wing aircraft (i.e. the limited ground checking) is partly circumvented by using a hand-held 35 mm SLR camera equipped with a macro-zoom lens (35-105 mm) and Kodacolor 64 ASA film. In low-level reconnaissance flights (150 to 250 m above the ground surface), the slides taken act as a field record to supplement field notes. During the long (five to six hours) transects, which are flown over consecutive days, broad to detailed photographs are taken and the location and view of each shot is referenced on a 1:250,000 topographic map for later analyses. The detailed photographs tend to offset the restricted ability of fixed-wing aircraft to provide frequent ground checks. In northern environments, where dense forest does not mask the ground surface, low-level flights and detailed slides enable us to readily identify environmental indicators such as structure and function of tundra plant communities, micro-landforms, and frost-induced features. This in part checks the lack of numerous ground inspections.

LANDSAT frames are normally carried in the field; they provide a quick reference to make contingency transects when localized weather fronts are unfavorable over planned flight transects. This is often crucial as the field reconnaissance is sometimes limited to one diagonal pass over each map sheet.

Postfield Stage

In this stage, the findings of the two previous stages are integrated. LANDSAT is reviewed and the 35 mm color slides are examined in a highly magnified form using a microfiche reader. Much data which was time-wise impossible to record while on flight transects is extracted and related to both the LANDSAT and the pretyped ecodistricts. Considering the new data, the maps and descriptions are finalized. The postfield integration of results is the most time-consuming of the three stages.

LANDSAT VISUAL ANALYSIS

For the purposes of this symposium, some aspects which LANDSAT imagery fulfilled in deriving basic data are outlined. Perhaps expressed differently from the terminology used by some other authors, the main indicators used in interpreting Color I LANDSAT images are:

- color (hue, value, and chroma);
- form associated with each color; and
- the pattern of color and form mixtures.

Once analyzed, these indicate details on the map units or on the ecological characteristics which are inherent to each unit.

The application of LANDSAT to map unit definition provides clues as to the nature of the boundary and the contents of the unit. Boundary lines of ecodistricts range from those which show marked contrasts through to those which are less obvious. Units A and C (Figure 1.1) illustrate sharply defined units, whereas the boundaries between L and M (Figure 1.3), between O and Q (Figure 1.4), and between E and C (Figure 1.1) are less distinct. In the latter cases, even the poorly contrasting units on LANDSAT are valuable because they flag areas that require more analysis and effort at a more detailed stage of remote sensing.

LANDSAT also reflects the relative mix of map unit characteristics. As a parallel to poorly defined boundaries, the more intricate the mix is, the more intensive is the effort needed at lower stages to maintain a similar level of mapping intensity. Map units are commonly sorted into "simple" or "composite" types. For a simple map unit (e.g. unit A, Figure 1.1), the color is fairly even and there tends to be only one form associated with the unit; this suggests that the biological and physical characteristics inherent to this large unit are relatively consistent and predictable in location. Composite units, on the other hand, generally contain a mix of characteristics; there are usually two or more dominant parent materials, plant communities, groups of soils, types of water bodies, etc. Composite map units can be further subdivided into two main types, the breakdown being related to the

periodicity of characteristics. Where the mix of characteristics is regularly recurrent throughout the unit, the characteristics and spatial locations are reasonably predictable. Map units F (Figure 1.2) and J (Figure 1.3) are examples. For units D (Figure 1.1), L (Figure 1.3), and O (Figure 1.4), however, the characteristics and their spatial locations are highly irregular and unpredictable. The range of colors, forms, and patterns of colors and forms indicate much of this. Table 3 summarizes patterns of colors, forms, and color/form mixes which can be expected for simple and composite (predictable and unpredictable) map units. The implication behind sorting map units in this manner is to provide some indication of the effort that will be required at the next level of sampling. To maintain a similar level of mapping intensity throughout, the composite units, especially the unpredictable types, will need more work at the aerial photography stage to provide a consistent degree of information for each map unit.

The capacity to extract data about each map unit is linked to the resolution of the image. Although the pixel is roughly 0.5 hectares, the edge and averaging effect of the spectral signatures usually dictate that land or water features must be in excess of 5 hectares to be clearly detected at this stage of remote sensing. In ecodistrict land classification, therefore, although some "local" featues may be identified, LANDSAT is more appropriate for "regional" features — commonalities which hold over fairly large tracts (1,000 to 3,000 km^2). Regional landforms (e.g. a marine plain, a rocky upland plateau, or a drumlinoid morainal plain), regional drainage and lake systems, and broad vegetative communities and cover types are easily distinguished. Many local features, such as individual drumlins (see map unit Z) or small valley deposits (see map unit Y), are often readily detectable. Even where an intense mixture of color and shape obscures small order landforms, however, this combination suggests where greater effort must be spent at a more-detailed level. LANDSAT also provides a quick indication of the abundance of regional and some local features. To a certain extent, dynamic phenomena can be ascertained from even just a single set of early summer images; for instance, stream and river bank erosion, deflated fluvial materials, or shorezone erosion are often apparent.

The role of terrain and vegetation indicators, as derived from LANDSAT, has been discussed in some lenth in the existing literature. The application of water indicators to interpret terrain or water features has, however, been discussed less frequently. In the northwestern District of Keewatin project area, much of the data interpreted from LANDSAT were derived from water-related indicators. In this area, where there are not marked changes in relief, surficial materials, and vegetative communities over large tracts, marked spectral signatures would not be expected to be recorded in relation to the terrain proper. Water indicators, however, were used in the absence of distinctive terrain indicators. Table 4 shows the indicators, how they are expressed in relation to some lakes, and what features they suggest. Similar interpretation keys were derived based on river indicators.

TYPE OF MAP UNIT	INDICATORS			FURTHER EFFORT REQUIRED*
	Color	Form	Color/Form Mix	
Simple	Small range and relatively homogeneous throughout unit	Fairly uniform throughout unit	N/A	Little
Composite: predictable	Variable and often contrasting colors	Variable and contrasting form types	Recurrent pattern	Moderate to considerable
Composite: unpredictable	Highly variable and often contrasting colors	Highly variable and contrasting form types	Irregular pattern	Considerable

* i.e. additional work that must be done using more-detailed remote sensing imagery (e.g. black-and-white aerial photographs) to maintain a constant level of detail for a given intensity of mapping.

Table 3: Map unit type and its relationship to indicators.

Lake Color	Lake Form	Color/Form Mix	Feature
Dark blue to blackish (clear)	Round, small-to-medium sized lakes aligned perpendicular to glacial ice movement	N/A	Terminal moraine
Dark blue to blackish (clear)	Elongated lakes, oriented parallel to ice movement; shorelines smooth	N/A	Drumlinized moraine
Dark blue or blackish to pallid (turbid)	Oblong (ovoid to rectangular) lakes, oriented parallel to ice movement; shorelines smooth or scalloped	Irregular	Drumlinized moraine mixed with marine materials
Pallid to whitish (turbid)	Round to ovoid lakes with the long axis usually oriented; shoreline smooth to scalloped	N/A	Marine material
Dark blue to blackish (clear)	Dendritic lobate with irregular orientation; shoreline angular	N/A	Bedrock
Dark blue to blackish (clear)	Dendritic lobate to irregular lakes with irregular orientation; shoreline angular to irregular	Irregular	Bedrock mixed with some moraine
Dark blue to blackish (clear)	Large, elongated lakes mixed with small, roundish lakes; oriented to glacial ice movement; roundish lakes somewhat randomly distributed, with shorelines smooth but irregular	Irregular	Drumlinized moraine along with terminal moraine
Dark blue to blackish (clear)	Ovoid to squarish lakes of variable size, often with the long axis oriented perpendicular to the long axis of map unit	N/A	Valley train and pitted outwash

Table 4: LANDSAT indicators as applied to lakes.

REFERENCES

CCELC (1979), Terminology (comp. by E.B. Wiken), Newsletter No. 6 of the Canada Committee on Ecological (Biophysical) Land Classification, Lands Directorate, Envir. Can., Ottawa, pp. 3-5.

Dyrness, C.T. and L.A. Viereck (1979), A Suggested Classification for Alaskan Vegetation, Fourth Revision, For. Serv., U.S. Dept. of Agric., Fairbanks, Alaska, 52pp.

Wiken, E.B. (1980), Rationale and Methods of Ecological Land Surveys: An Overview of Canadian Approaches, Land/Wildlife Integration. Proceedings of a Technical Workshop to Discuss the Incorporation of Wildlife Information into Ecological Land Surveys, 1 and 2 May 1979, Saskatoon, Sask., Ecol. Land Classif. Ser., No. 11, Lands Directorate, Envir. Can., Ottawa, pp. 11-19.

Wiken E. and D. Welch (1979), An Interdisciplinary Basis for Resource Studies: The Ecological Land Survey, Proceedings: Resource Inventory Workshop, Whitehorse, Yukon Terr, 16-18 Oct. 1979, pp. 33-50, Govt. of Yukon, Whitehorse, Yukon Terr.

Date Due

Due Can NOV 22 '95

RETURN NOV 09 '95

43849

Pam: 528.7:(*41N) WIK

WIKEN, E.B. et al.

Multistage remote sensing in exploratory .....

#43489

BOREAL INSTITUTE FOR NORTHERN STUDIES, LIBRARY
THE UNIVERSITY OF ALBERTA
EDMONTON, ALBERTA T6G 2E9
CANADA

LANDS DIRECTORATE
received
JUL 10 1980
DIRECTION GENERALE
DES TERRES
reçu

University of Alberta Library
0 1620 0329 3204